# PATENT SPECIFICATION 817,660

*Inventors:*—
CUTHBERT MARKLEW TUNSTALL, THOMAS GREAVES WRIGHT,
WILLIAM SAMUEL POLLINGER and BASIL DAVENPORT BLACKWELL.

*Date of filing Complete Specification: May 22, 1956.*

*Application Date: May 27, 1955. No. 15464/55.*

*Complete Specification Published: Aug. 6, 1959.*

Index at Acceptance:—**Class 83(2), A166.**

**International Classification:—B23p.**

COMPLETE SPECIFICATION.

## Improvements in or relating to Blades for Gas Turbines.

We, BRISTOL AERO-ENGINES LIMITED, a British Company, of Stonebridge House, Colston Avenue, in the City and County of Bristol, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of making metal blades for use in gas turbine rotors, the said blades being of the kind, hereinafter referred to as the kind described, comprising a working portion of aerofoil section provided with longitudinally extending internal passages for conveyance of a cooling fluid, a root portion with abutment shoulders, through which centrifugal forces acting on the blade when in service are resisted, and a platform part between the working portion and the root portion, the working portion and the root portion extending on opposite sides of the platform part.

One method of making a blade of the kind described is to machine the blade from a blade blank having at least a lengthwise part of the same shape and dimensions in cross-section as the platform part of the blade, the blade blank also having internal passages running longitudinally through the blank, the passages being of such size and so disposed in the blank as to form the required passages in the blade which is formed from the blank.

A convenient method of forming such a blank is by extrusion, but it will be appreciated that other methods may be used.

In cases in which the internal passages in the blank would break through or approach too closely the abutment shoulders of the root portion of a blade to be machined from the blank however, the method outlined above for making a blade of the kind described is unacceptable, and the object of the present invention is to supplement the method previously outlined in a manner such as to render it acceptable from the point of view discussed.

According to the present invention there is provided a method of making a blade of the kind described from a blade blank of which at least that portion extending lengthwise from one end, for a distance sufficient to enable the root portion and the platform part to be formed therefrom, has substantially the same shape and dimensions in cross-section as the platform part of the blade to be formed from the blank, the blade blank also having internal passages running longitudinally through the blank, the passages being of such a size and so disposed in the blank as to form the required passages in the blade which is to be formed from the blank, which method comprises forming the root portion of the blade by cutting an open ended slot from said one end of the blank to a depth not exceeding the length of the root portion of the blade which is to be formed from the blank, forging the blank to press the prongs thus formed into contact with one another whereby the slot is closed at said one end of the blank, and then machining a portion of the blank at said one end of the blank to produce the root portion of the blade, the size, form and disposition of said slot being such that after the forging operation said portion of the blank can be machined to the required root form without any of said passages breaking

through any load carrying abutment shoulder of the root.

According to a feature of the present invention the root portion of the blade may be formed with the abutment shoulders of the root extending parallel with the plane of contact, of the prongs. Alternatively however, according to another feature of the present invention, the root portion of the blade may be formed with the abutment shoulders of the root extending substantially perpendicular to the plane of contact of the prongs so that the said plane intersects the sides of the root provided with the abutment shoulders.

According to another feature of the present invention said blade blank may be an extruded bar which has a cross-section of substantially the same shape and dimensions as the platform part of the blade to be formed from the blank and a length substantially equal to the length of the blade to be formed from the blank, and said method may further comprise machining another portion of the blank to produce the aerofoil cross-sectioned working portion of the blade.

According to another feature of the present invention said slot may be so formed as to be bounded in part by flat surfaces which meet the end surface of the blade blank at said one end of the blank in parallel lines which bound on said end surface an area which contains all the openings to said internal passages at said one end of the blank, so that when said prongs are pressed into contact with one another as aforesaid, said internal passages are closed at said one end of the blank.

Usually, the parallel lines bound the minimum area of said end surface of the blank to encompass all the internal passages.

It will be appreciated however that where sufficient metal is available outside the passages said parallel lines may be more widely spaced, and that where it is not necessary for the passages to be closed at the end of the blank the parallel lines may be more norrowly spaced.

According to yet another feature of the invention said slot may be formed with said flat bounding surfaces parallel to one another and with said surfaces joined by a curved boundary surface at the base of the slot, and said prongs may be pressed into contact with one another over part only of the extent of said flat bounding surfaces from said one end of the blank thereby leaving a passage of tear-drop shaped cross-section extending transversely of and in communication with all said internal passages.

Alternatively however according to yet another feature of the invention said slot may be formed with said flat bounding surfaces inclined relatively to one another to give a V-sectioned slot of a depth not greater than the length of the root portion of the blade which is to be formed from the blank.

Two methods in accordance with the present invention of making a blade of the kind described having a "fir tree" type of root will now be described merely by way of example with reference to the drawings accompanying the Provisional Specification whereof:—

Figure 1 is a plan view of a finished blade looking from the tip of the working portion of the blade towards the platform part of the blade;

Figure 2 is a longitudinal section corresponding to the line 3—3 in Figure 1 through the root portion of a blade blank after an initial stage of forming the root according to the first method which is about to be described;

Figure 3 is a similar section through the finished root; and

Figures 4 and 5 show two stages in the formation of the root portion of a blade according to the second method which will hereinafter be described.

The blade shown in Figure 1 comprises a platform part 1 of parallelogram shape in plan view. From one face of the platform part projects a working portion 2 of aerofoil section and from the other face a root portion 3, not visible in Figure 1 but shown in Figure 3, comprising a "fir tree" root 4 with abutment shoulders 5 and an "extended" root portion part 6 between the last of the abutment shoulders and the platform part. Extending longitudinally through the working portion 2 and the platform part 1 are four parallel passages 7, 8, 9 and 10 for conveyance of a cooling fluid, such cooling fluid being admitted into the passages through four ports *7a*, *8a*, *9a* and *10a* in the "extended" part 6 of the root portion.

As may be seen from Figure 1 the passages 7, 8, 9, and 10 lie on an arc which follows the curve of the convex and concave surfaces of the working portion 2 of the blade.

A blade of this kind is conveniently made from a blade blank in the form of a length of extruded bar substantially equal in length to the finished blade and having a cross-section corresponding in shape and dimensions, apart from a machining allowance, to the plan view of the platform part 1, the extrusion being formed, by methods which do not form part of the present invention, with longitudinally extending internal passages so that the blade blank has such passages running through it, the passages being of such size and so disposed in the blank as to form the passages 7, 8, 9 and 10 of the blade which is to be made from the blank. As will be seen from the dotted line

11 in Figure 3 the passage 8 would, if the root portion 3 were machined upon an end portion of the unpretreated blank, break through the first of the abutment shoulders 5 on the left hand side of the root portion and would pass undesirably close to the other abutment shoulders on that side of the root portion, so much so that the root portion would be seriously weakened. To a lesser extent the other passages 7, 9 and 10 would also weaken the root portion.

To overcome this objection an open ended slot 12 is cut in the end surface 30 of the end portion of the blank from which the root portion 3 is to be formed. The slot is cut to a depth equal to the length of the root portion 3 and so as to be bounded on opposite sides by flat parallel surfaces 13 and 14, which extend parallel with the passages 7 to 10. As will be seen from Figure 1 the surfaces 13 and 14 meet the end surface 30 in parallel lines 31, 32 respectively which bound on the surface 30 an area which contains all the openings to the passages 7, 8, 9 and 10 in the surface. Of the lines 31, 32 the line 32 is the common tangent to the openings in the surface 30 to the passages 7 and 10, which passages are the passages spaced most widely in the chordal direction of the blade which is to be formed from the blank, on the side of the passages 7 and 10 which will be nearest the thrust face of the blade. The line 31, on the other hand, is coincident with that tangent to one of passages 7 to 10 which is spaced furthermost from line 32. In the present example, the line 31 is the tangent to that side of the opening to the passage 8 which will be nearest the back surface of the blade. In the present example, since the surfaces 13 and 14 are parallel to the passages 7 to 10 it will be appreciated that the surfaces 13 and 14 are also tangent surfaces to the passages 7 and 10, and 8 respectively. Thus the slot 12 in effect cuts out only the metal of the end portion of the blank which is to form the root portion which contains the passages 7 to 10. At the base of the slot the surfaces 13 and 14 are joined by a cylindrical boundary surface 15.

By cutting the slot 12 two prongs 16 and 17 are formed at the end of the blade blank, and these are now forged into contact with one another as shown by the dotted lines in Figure 2 over part only of the extent of the surfaces 13 and 14 from the end surface 30 of the blank, a rod of hard material preferably being inserted in the bottom of the slot to maintain the radius 15. The two prongs contact one another over a flat surface 18 which is arranged to lie in a plane through the centre of gravity of the finished blade which plane will, when the blade is mounted on a turbine wheel, be radial to the axis of the wheel and the root portion is itself formed as hereinafter described so as to lie symmetrically on each side of the surface 18. To achieve the correct disposition of the surface 18 with the configuration shown the prong 17 has to be pressed inwardly rather more than the prong 16. The forged part of the blank is now machined to form the root portion 3 as shown in Figure 3 and the other end portion of the blank, on the opposite side of the platform-forming part 1, is machined to form the aerofoil sectioned working portion 2 of the blade. If required, a shroud can also be provided at the tip of the blade.

On completion of this machining a blade is obtained having longitudinal passages 7, 8, 9 and 10 running into a passage 19 of tear-drop shape extending transversely through the extended root part 6. If desired, this passage may be used as an inlet for the cooling fluid, one end being possibly closed by a plate brazed to the side face 33 or the side face 34 of the root, or both ends may be closed, and inlet ports *7a*, *8a*, *9a* and *10a* drilled through into the passage 19 from the sides of the extended root part 6.

In the second method the blade root portion 3 is formed by cutting the slot 12 in V section instead of with parallel sides, the apex of the V being located below the platform-forming part of the blade blank and ending in a stress relieving drilling 20. Like the surfaces 13 and 14 of the parallel sided slot shown in Figure 2, the surfaces 21 and 22 of the V slot meet the end surface 30 of the blank in parallel lines which may be disposed in relation to the openings to the passages 7 to 10 in the surface 30 as previously described with reference to the lines 31 and 32. In the present example they are however more widely spaced than this as may be seen from Figure 4. In any case, when the prongs 16 and 17 thus formed are forged into contact with one another along the surfaces 21 and 22, as shown by the dotted lines in Figure 4, the passages 7 to 10 are completely closed at the forged end of the blank. After machining the forged end portion of the blank to form the root portion 3 as shown in Figure 5, the drilling 20 may be opened out and used as a cooling fluid supply passage or header passage, one or both ends of the drilling possibly being plugged.

Whilst the minimum requirement is that the internal passages such as 7 to 10 should not break through any of the abutment shoulders, such as 5, of the root portion, it is desirable so to dimension and position the slot such as 12 as to obtain a maximum thickness of solid metal in the vicinity of the root serrations.

It should be understood that the invention is applicable to the manufacture of blades of the kind described which have

other than "fir tree" type roots, and the blade blanks may be made by forging instead of by extrusion, in which case the working portion of the blade may be either rough forged on the blank for finishing by machining or may be precision forged on the blank so as to require only polishing.

Where, either in an extruded or a forged blank, the internal passages such as 7 to 10 extend over so much of an arc in the working portion of the blade that a slot in the root would have to be of impracticably great width to contain them, the root portion may be subjected to a preliminary forging operation to flatten the arc of distribution of the passages sufficiently to reduce to an acceptable value the width of the slot which has to be cut.

Whilst in the embodiments shown the root is formed with the abutment shoulders extending parallel to the common plane of contact of the prongs formed on the blank by the slotting process, the root could alternatively be formed with the abutment shoulders extending substantially perpendicular to the said common plane so that the said plane intersects the sides of the root provided with the abutment shoulders.

In this case the root might be designed to fit into a circumferential slot in a turbine rotor disc the abutment shoulders lying along large radius arcs centered on the axis of the rotor of which the blade is to form a part. In this case also, the platform part would be curved and centered on said axis.

WHAT WE CLAIM IS:—

1. A method of making a blade of the kind described from a blade blank of which at least that portion extending lengthwise from one end, for a distance sufficient to enable the root portion and the platform part to be formed therefrom, has substantially the same shape and dimensions in cross-section as the platform part of the blade to be formed from the blank, the blade blank also having internal passages running longitudinally through the blank, the passages being of such a size and so disposed in the blank as to form the required passages in the blade which is to be formed from the blank, which method comprises forming the root portion of the blade by cutting an open ended slot from said one end of the blank to a depth not exceeding the length of the root portion of the blade which is to be formed from the blank, forging the blank to press the prongs thus formed into contact with one another whereby the slot is closed at said one end of the blank, and then machining a portion of the blank at said one end of the blank to produce the root portion of the blade, the size, form and disposition of said slot being such that after the forging operation said portion of the blank can be machined to the required root form without any of said passages breaking through any load carrying abutment shoulder of the root.

2. A method as claimed in Claim 1, in which the root portion of the blade is formed with the abutment shoulders of the root extending parallel with the plane of contact of the prongs.

3. A method as claimed in Claim 1, in which the root portion of the blade is formed with the abutment shoulders of the root extending substantially perpendicular to the plane of contact of the prongs so that said plane intersects the sides of the root provided with abutment shoulders.

4. A method as claimed in Claim 1, 2 or 3 wherein said blade blank is an extruded bar which has a cross-section of substantially the same shape and dimensions as the platform part of the blade to be formed from the blank and a length substantially equal to the length of the blade to be formed from the blank, and said method further comprises machining another portion of the blank to produce the aerofoil cross-sectioned working portion of the blade.

5. A method as claimed in any one of the preceding claims wherein said slot is so formed as to be bounded in part by flat surfaces which meet the end surface of the blade blank at said one end of the blank in parallel lines which bound on said end surface an area which contains all the openings to said internal passages at said one end of the blank, so that when said prongs are pressed into contact with one another as aforesaid, said internal passages are closed at said one end of the blank.

6. A method as claimed in Claim 5, wherein said parallel lines bound the minimum area of said end surface of the blank to encompass all the internal passages.

7. A method as claimed in Claim 5 or Claim 6, wherein said slot is formed with said flat bounding surfaces parallel to one another and with said surfaces joined by a curved boundary surface at the base of the slot, and wherein said prongs are pressed into contact with one another over part only of the extent of said flat bounding surfaces from said one end of the blank thereby leaving a passage of tear-drop shaped cross-section extending transversely of and in communication with all said internal passages.

8. A method as claimed in Claim 7, further comprising closing one end of said transverse passage so as to leave a single opening in the blade root in communication with said internal passages.

9. A method as claimed in Claim 7, further comprising closing each end of said transverse passage and then forming one or

more inlet ports in the blade root which inlet ports communicate with said transverse passage.

10. A method as claimed in Claim 5 or Claim 6, wherein said slot is formed with said flat bounding surfaces inclined relatively to one another to give a V-sectioned slot of a depth not greater than the length of the root portion of the blade which is to be formed from the blank.

11. A method as claimed in Claim 10, further comprising forming a stress relieving drilling at the apex of the slot.

12. A method as claimed in Claim 11, wherein said stress relieving drilling intersects at least one of said internal passages, and the method further comprises, after forming said root portion, opening out part of the drilling for use as an inlet to said one of said internal passages.

13. A method as claimed in any one of Claims 5 to 12, wherein said prongs are pressed into contact with one another over a flat surface which lies in the plane of symmetry of the root portion of the blade to be formed from the blank.

14. A method as claimed in Claims 1, 2 or 3 or any one of Claims 5 to 13, wherein said blade blank is a forging.

15. A method as claimed in Claim 14, wherein said blade blank has a lengthwise extending portion at the other end thereof which is rough forged to the shape of the aerofoil cross-sectioned working portion of the blade to be formed from the blank, and the method further comprises machining the rough forged portion of the blank to produce the aerofoil cross-sectioned working portion of the blade.

16. A method as claimed in Claim 14, wherein said blade blank has a lengthwise extending portion at the other end thereof which is precision forged to the shape of the aerofoil cross-sectioned working portion of the blade to be formed from the blank, and the method further comprises polishing the aerofoil cross-sectioned working portion.

17. A method as claimed in any one of the preceding Claims 5 to 16, further comprising subjecting said lengthwise extending portion of the blank at said one end of the blank to a preliminary forging operation before machining said slot in order to flatten any arc of distribution of said internal passages to reduce the width required for said slot.

18. A method of making a blade of the kind described, substantially as hereinbefore described with reference to Figures 1, 2 and 3 of the drawings accompanying the Provisional Specification.

19. A method of making a blade of the kind described, substantially as hereinbefore described with reference to Figures 4 and 5 of the drawings accompanying the Provisional Specification.

20. A blade of the kind described when made by a method as claimed in any one of the preceding claims.

BOULT, WADE & TENNANT,
111 & 112 Hatton Garden,
London, E.C.1.
Chartered Patent Agents.

## PROVISIONAL SPECIFICATION.

## Improvements in or relating to Blades for Gas Turbines.

We, BRISTOL AERO-ENGINES LIMITED, a British Company, of Stonebridge House, Colston Avenue, in the City and County of Bristol, do hereby declare this invention to be described in the following statement:—

This invention relates to a method of making metal blades for use in gas turbine rotors, the said blades being of the kind, hereinafter referred to as the kind described, comprising a working portion of aerofoil section provided with longitudinally extending internal passages for conveyance of a cooling fluid, a root portion with abutment shoulders, through which centrifugal forces acting on the blade when in service are resisted, and a platform part between the working portion and the root portion, the working portion and the root portion extending on opposite sides of the platform part. The invention also includes the blades of the kind described when made by the method according to the invention.

In one method of making a blade of the kind described, at least the working portion and an adjacent part of the platform is machined from an extruded bar which has a cross-section of substantially the same shape and dimensions as the platform and has longitudinally extending passages of the size and disposition of the passages required in the blade.

In cases in which the internal passages would break through or approach too closely the abutment shoulders of the root portion in an unacceptable manner, if the root portion was also machined from the extruded bar, it is possible to form the root from a solid metal blank butt welded to an end of the extruded bar.

The present invention provides an alternative method, not involving welding, of forming the root portions on blade blanks, whether made by extrusion or otherwise, which blade blanks have passages running

longitudinally through a part which is of substantially the same shape and dimensions in cross-section as the platform part and from which the root portion is to be formed.

According to the present invention the root portion of a turbine blade of the kind described is formed from part of a blade blank, which part is of substantially the same shape and dimensions in cross-section as the platform part and has passages running longitudinally through it, by machining a slot in the root end of the blade blank for a length not exceeding the length of the root portion of the blade, forging the blank to press the prongs thus formed into contact with one another over at least part of their length from the end of the blank, and machining the blank to produce a blade root portion at the said forged end, the size, form and disposition of the said slot being such that after forging the slotted end of the blank the said end can be machined to the root form without any of said passages breaking through any load-carrying abutment shoulder of the root.

According to a feature of the invention a turbine blade of the kind described may be made from an extruded bar which has a cross-section of substantially the same shape and dimensions as the platform, a length substantially equal to the length of the finished blade, and has longitudinally extending internal passages of the size and disposition of the passages required in the blade, the said blade being made by machining a slot in one end of the bar for a length not exceeding the length of the root portion of the blade, forging the bar to press the prongs thus formed into contact with one another over at least part of their length from the end of the bar, and machining the forged part of the bar to provide a blade root portion and another part of the bar to provide a working portion of aerofoil section, the size, form and disposition of the said slot being such that after forging the bar the forged end can be machined to the root form without any of said passages or the walls of the slot breaking through any load-carrying abutment shoulder of the root.

According to a further feature of the invention the slot is so formed as to be bounded at least in part by flat surfaces which meet the end surface of the bar in parallel lines one of which is tangent to those sides of the walls of the passages most widely spaced in the chordal direction of the blade blank which will be nearest the thrust face of the blade and the other of which is tangent to that passage side which is spaced furthest from the first said tangent, so that when the prongs thus formed are pressed into contact with one another at the end of the bar the passages are thereby closed at that end.

According to a further feature of the invention the flat slot boundary surfaces referred to in the preceding paragraph are formed parallel to one another and joined by a curved boundary surface at the base of the slot and the prongs thus formed are pressed into contact with one another over part of the extent of said flat surfaces from the end of the bar, leaving a passage of tear-drop shaped cross-section extending transversely of and connected to all said longitudinally extending passages.

The invention is illustrated in the accompanying drawing which shows by way of example two methods of forming a "fir tree" type of root on a blade of the kind described.

In the drawing:—

Figure 1 is a plan view of a finished blade looking from the tip of the working portion towards the platform.

Figure 2 is a longitudinal section corresponding to the line 3—3 in Figure 1 through the root portion of a blade blank after an initial stage of forming the root.

Figure 3 is a similar section through the finished root.

Figures 4 and 5 similarly show two stages in a modified method of forming a root.

The blade shown in Figure 1 comprises a platform part 1 of parallelogram shape in plan view. From one face of the platform part projects a working portion 2 of aerofoil section and from the other face a root portion 3, not visible in Figure 1 but shown in Figure 3, comprising a "fir tree" root 4 with abutment shoulders 5 and an "extended" root portion 6 between the last of the abutment shoulders and the platform part. Extending longitudinally through the working portion 2 and the platform part 1 are four passages 7, 8, 9 and 10 for conveyance of a cooling fluid, such cooling fluid being admitted into the passages through four ports *7a*, *8a*, *9a* and *10a* in the "extended" portion 6 of the root.

A blade of this kind is conveniently made from a length of extruded bar substantially equal in length to the finished blade and having a cross-section corresponding in shape and dimensions, apart from a machining allowance, to the plan view of the platform 1, the extrusion being formed, by methods which do not form part of the present invention, with longitudinally extending passages of the size and disposition of the passages 7, 8, 9 and 10 of the finished blade. As will be seen from the dotted line 11 in Figure 3 the passage 8 would, if the root were machined upon the end of an unpretreated length of extruded bar, break through the first of the abutment shoulders 5 on the left hand side of the root

and would pass undesirably close to the other serrations on that side of the root, so much so that the root would be seriously weakened. To a lesser extent the other passages 7, 9 and 10 also weaken the root.

To overcome this objection a slot 12 is cut in that end of the length of bar, constituting the blank, from which the root is to be formed. The slot extends longitudinally along the bar for a length equal to the length of the root portion 3 and is bounded on opposite sides by flat parallel surfaces 13 and 14, see also Figure 1. The surface 13 is tangent to those sides of the walls of the passages 7 and 10 spaced most widely in the chordal direction of the blade blank which will be nearest the thrust face of the blade, while the surface 14 is tangent to that passage side which is spaced furthest from the surface 13, that is to say, to that side of the passage 8 which will be nearest the back surface of the blade. Thus the slot in effect cuts out only the metal of the root part of the blank containing the passages. At the base of the slot the surfaces 13 and 14 are joined by a cylindrical boundary surface 15.

Two prongs 16 and 17 are thus formed at the end of the blade blank and these are now forged into contact with one another as shown by the dotted lines in Figure 2, a rod of hard material preferably being inserted in the bottom of the slot to maintain the radius 15. The two prongs contact one another over a flat surface 18 which is preferably arranged to lie in the plane of symmetry of the finished root, which should itself lie in a radial plane through the centre of gravity of the blade. To achieve this with the configuration shown the prong 17 has to be pressed inwardly rather more than the prong 16. The forged part of the blank is now machined to the blade root profile as shown in Figure 3 and another part of the blank, on the opposite side of the platform-forming part, is machined to the required aerofoil section profile. If required, a shroud can also be provided at the tip of the blade.

On completion of this machining a blade is obtained having longitudinal passages 7, 8, 9 and 10 running into a passage 19 of tear-drop shape extending transversely through the extended root part 6. If desired, this passage may be used as an inlet for the cooling fluid, one end being possibly closed by a plate brazed to the end of the root, or both ends may be closed, and inlet ports 7*a*, 8*a*, 9*a* and 10*a* drilled through into it from the sides of the extended root part 6.

In a modified method of forming the blade root illustrated in Figures 4 and 5 the slot 12 is of V section instead of having parallel sides, the apex of the V being located below the platform-forming part of the blade blank and preferably ending in a stress relieving drilling 20. Like the surfaces 13 and 14 of the parallel sided slot shown in Figure 2, the surfaces 21 and 22 of the V slot meet the end surface of the bar in parallel lines and these lines can also be tangent to oppositely directed sides of the passages 7, 10 and 8, or they can be somewhat more widely spaced than this, as shown in Figure 4. In any case, when the prongs 16 and 17 thus formed are forged into contact with one another along the V groove surfaces, as shown by the dotted lines in Figure 4, the passages are completely closed at that end of the blank. After machining the root profile, as shown in Figure 5, the drilling 20 may be opened out and used as a cooling fluid supply passage or header passage, one or both ends possibly being plugged.

Whilst the minimum requirement is that the longitudinal passages should not break through any of the abutment shoulders 5, it will be desirable so to dimension and position the slot as to obtain a maximum thickness of solid metal in the vicinity of the root serrations.

The invention is applicable to blades with other than "fir-tree" type roots, and the blade blanks may be made by forging instead of by extrusion, in which case the working portion of the blade may be either rough forged for finishing by machining or may be precision forged so as to require only polishing.

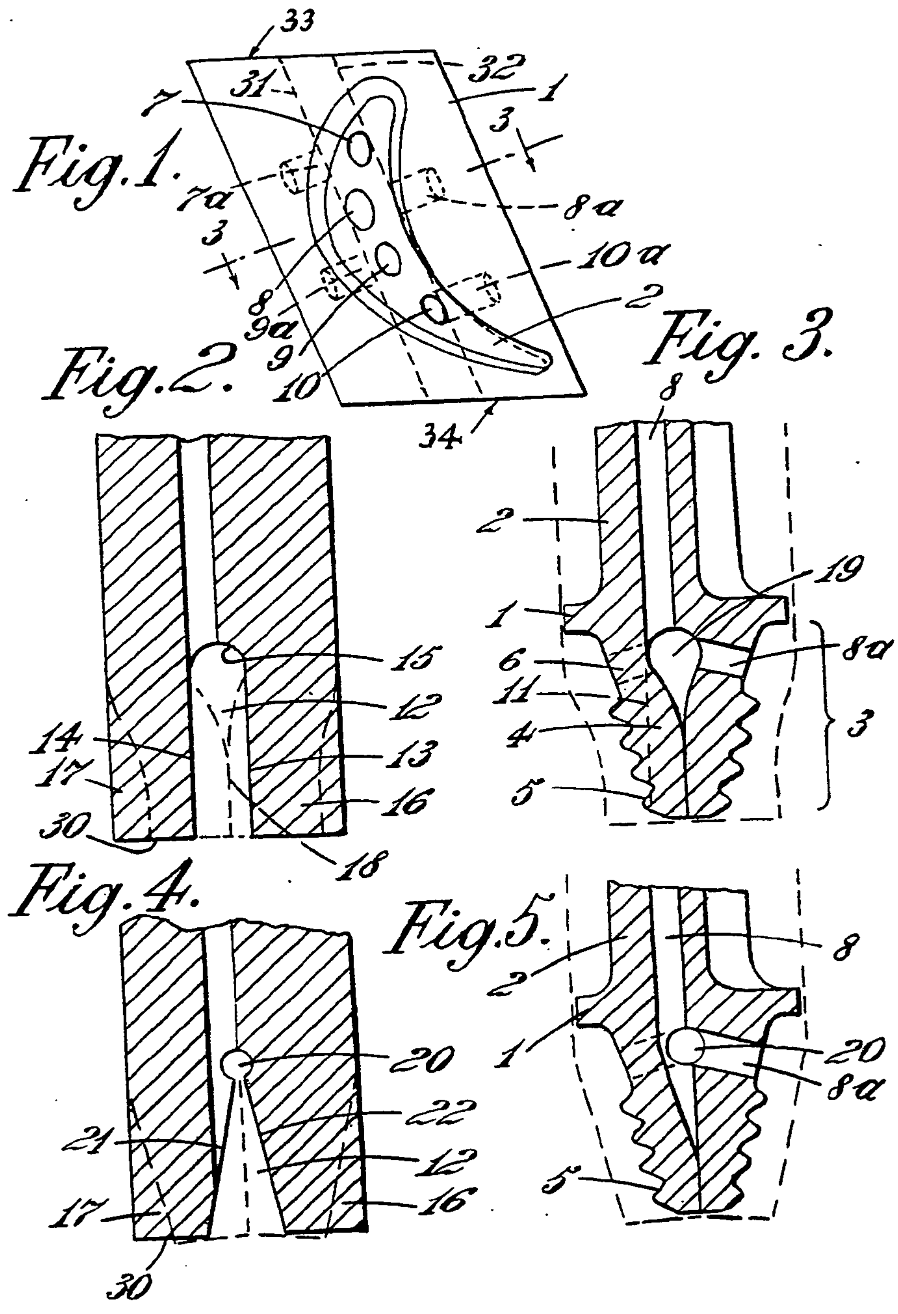
Where, either in an extruded or a forged blank, the cooling passages extend over so much of an arc in the working portion of the blade that a slot in the root would have to be of impracticably great width to contain them, the root portion may be subjected to a preliminary forging operation to flatten the arc of distribution of the passages sufficiently to reduce the width of the slot to an acceptable value.

BOULT, WADE & TENNANT,
111 & 112 Hatton Garden,
London, E.C.1.
Chartered Patent Agents.

Abingdon : Printed for Her Majesty's Stationery Office, by Burgess & Son (Abingdon), Ltd.—1959.
Published at The Patent Office, 25, Southampton Buildings. London, W.C.2,
from which copies may be obtained.

817,660 PROVISIONAL SPECIFICATION

I SHEET This drawing is a reproduction of the Original on a reduced scale.



XP-002233143

AN - 1979-41888B [22]
CPY - PRMO-R
DC - M21 P52
FS - CPI;GMPI
IC - B21H7/16 ; B21K3/04
IN - GERASIMOV D E; KABANOV Y U N; VAGANOV V P
MC - M21-H
PA - (PRMO-R) PERM MOTOR CONS WKS
PN - SU617144 A 19780717 DW197922 000pp
PR - SU19772451126 19770207
XIC - B21H-007/16 ; B21K-003/04
AB - SU-617144 Turbine and compressor blades can be made by heating the initial blank rolling periodically, cutting into separate blanks, heating again, shaping, forming the lock, calibrating and rolling. To improve precision, strips of shaped rhomboid cross-section are used as the initial blank. The heating before rolling is in molten salts at 850-1150 degrees C. for 2.5-5 mins. Before shaping the blade proper, heating is done in two stages in air: first at 600-700 degrees C, for 5-10 min. and finally at 850-1150 for 3-5 min.
- Since there is no need for heating in an inert gas, the cost of the process is reduced. The specific pressure in periodic rolling is reduced by 30%, so there is less wear on the rolling gear.
IW - TURBINE COMPRESSOR BLADE PRODUCE STRIP RHOMBIC CROSS-SECTION HEAT MOLTEN SALT ROLL TWO-STAGE AIR HEAT SHAPE BLADE
IKW - TURBINE COMPRESSOR BLADE PRODUCE STRIP RHOMBIC CROSS-SECTION HEAT MOLTEN SALT ROLL TWO-STAGE AIR HEAT SHAPE BLADE
INW - GERASIMOV D E; KABANOV Y U N; VAGANOV V P
NC - 001
OPD - 1977-02-07
ORD - 1978-07-17
PAW - (PRMO-R) PERM MOTOR CONS WKS
TI - Turbine and compressor blades prodn. - from strip of rhomboid cross=section involves heating in molten salts before rolling and two=stage air heating before shaping blade